Diurnal Zooplankton Ecology in a Phosphate Pit Lake

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Since 1961, several lakes in South Central Florida have been investigated over periods of from 12 to 15 months each to learn something of the annual cycles of physical, chemical, and biological features of the bodies of water. In this program of comparative limnology, the procedure has been to visit each lake once monthly at nearly the same clock hour. Since a lake is not a static ecosystem, even throughout a 24-hour period, the schedule allows for inherent, yet bothersome, questions; namely, are the data gathered at a given time each day sufficient to give a "typical" description, and what are the conditions at other hours? In an effort to obtain answers, at least to a small extent, investigations into the diurnal variations in oxygen and carbon dioxide content, *p*H, temperature, light attenuation, and zooplankton population dynamics through the water column of a small phosphate pit lake in the eastern part of Hillsborough County, Florida, were made in January, 1964.

The lake, designated "T-6" in a fisheries management program of the Florida Game and Fresh Water Fish Commission, is small, the surface area being about 9 hectares. It was formed by excavation attendant to mining for land pebble phosphate rock, and is one of numerous lakes thus formed in Polk and Hillsborough counties. The phosphorus content of the rock is in the form of tricalcium phosphate ("bone phosphate of lime"), ranging from 66 to 80 per cent $Ca_3(PO_4)_2$, thereby imparting a high content of this nutrient to the waters; studies (unpublished) of a nearby lake revealed concentrations of orthophosphate up to nearly 5 mg/liter. Sides of the basin are steep, dropping to a depth of about 6 m. The surface supports an abundant mass of "water lettuce," *Pistia stratiotes*, a floating spermatophyte. The bottom is devoid of vegetation.

Water samples for chemical determinations were taken with a 3-liter Foerst water sampler (Kemmerer-type), and the analyses were made immediately upon return to shore. Dissolved oxygen was measured by the Alsterberg (Azide) modification of the Wink-

ler method (APHA, 1960). Carbon dioxide was determined titrimetrically with NaOH and phenolphthalein (APHA, 1960). The *p*H was read from a Hellige Water Comparator with color discs and appropriate indicators from Hellige Corporation. Temperature was measured with a Whitney Electrical Underwater Thermometer from Whitney Instruments Company. Light attenuation (as per cent of surface illumination) was calculated from readings on a Whitney Underwater Daylight Meter with deck cell (Whitney Company) and a Secchi disc was also used. Plankton was captured in a 10-liter plankton trap (Juday type) with a net of No. 25 bolting silk; the organisms were concentrated in appropriate glass containers and the numbers counted (in duplicate) under magnification. Physical and chemical data were obtained from samples collected at one-meter intervals through the water columns, while plankton samples were taken at half-meter levels. Sampling was done at three-hour intervals on 8-9 and 20-21 January 1964.

The Environment

TEMPERATURE. As is characteristic of relatively shallow bodies of standing waters, generally, the temperature through the water column of Lake T-6 responded rapidly to variations in the ambient atmospheric temperature (Fig. 1). During the investigation of 8-9 January, the atmospheric temperature varied only 5.5 degrees, from 20.0 C-25.5 C, and the mean water temperature at a depth of 1 m throughout the 24-hour period was 18.6 C. The air temperature during the 20-21 January visit, however, ranged from 6.0 C-21.0 C, a difference of 15 degrees. Over this period, the mean temperature of the water at a depth of 1 m was 15.8 C. Figure 1 also shows that the entire water column responded to the atmospheric cooling, the temperature of the bottom waters dropping about one degree.

TRANSPARENCY. Lake T-6 is a highly turbid lake resulting, therefore, in low transparency. As shown in Fig. 2, the maximum depth of Secchi disc measurements during the 20-21 January period) was 92 cm at 1500 hours on 20 January. Light attenuation through the column was highest at noon on 21 January, at which time 0.4 per cent of surface illumination reached a depth of 3 meters.

DISSOLVED OXYGEN. Determinations of the dissolved oxygen content through the water column were made every

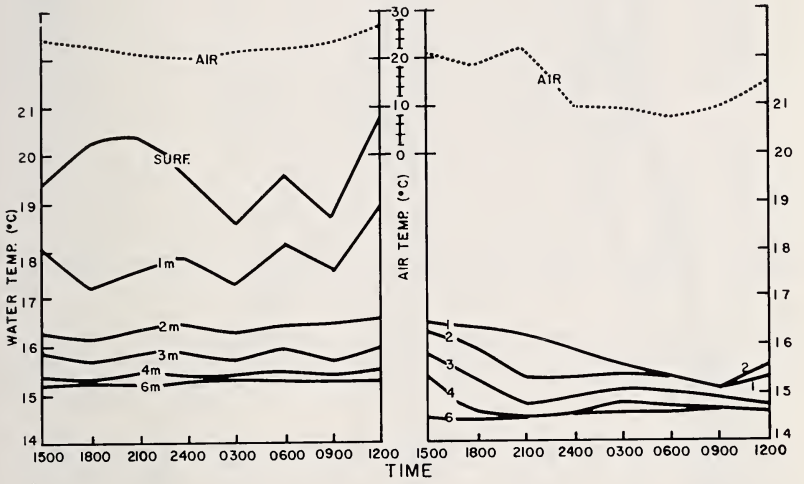

Fig. 1. Temperatures through the water column of Lake T-6 during the periods 8-9 (left) and 20-21 (right) January 1964. Ambient air temperatures are shown above and are referable to the scale between graphs. Temperatures at 5m depth are omitted.

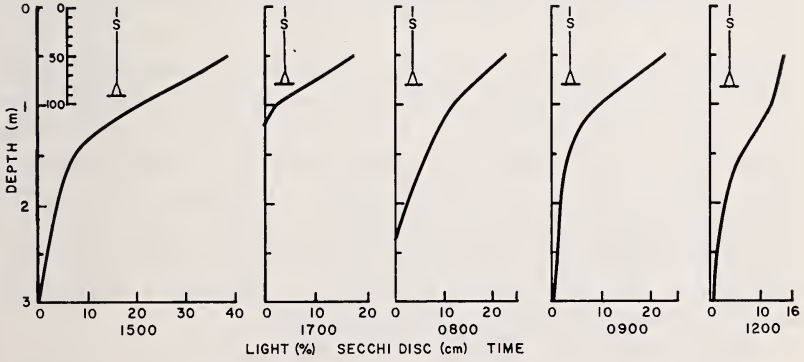

Fig. 2. Light attenuation through the water column during the day (20-21 January, 1964) expressed as per cent of surface illumination. Depths at which a Secchi disc disappeared are indicated at "S" and are referable to the scale (in centimeters) inset in the coordinates for 1500 hrs.

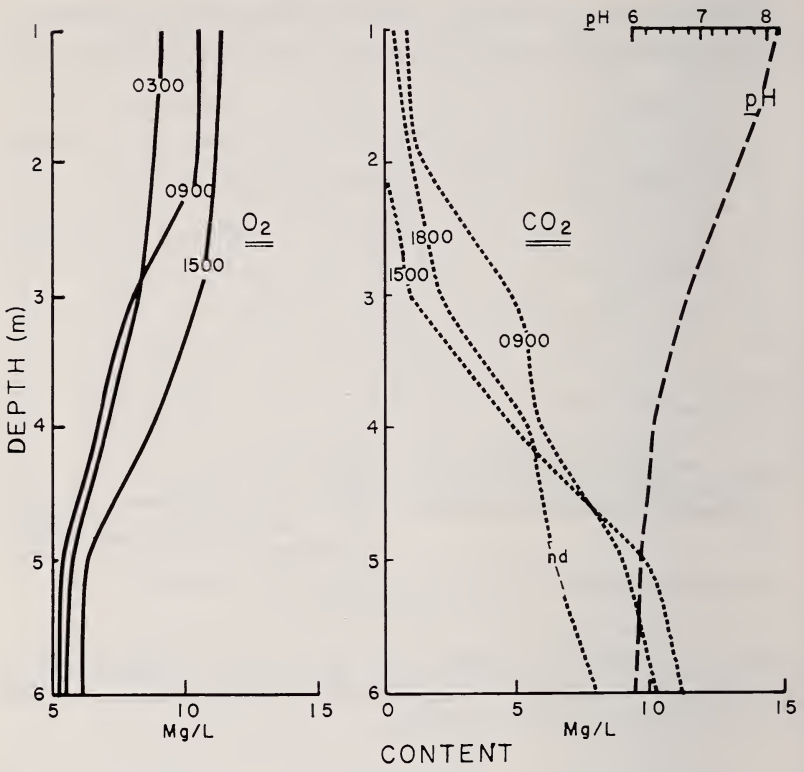

Fig. 3. Vertical *p*H measurements and content of oxygen and carbon dioxide (in milligrams per liter). Data of 8-9 January 1964.

three hours at one-meter intervals during the 8-9 January period. Three representative curves are shown in Fig. 3. The oxygen content of the bottom meter of water was low and varied little during the 24-hr. period, the range being from 5.0-6.2 mg-liter. Near surface, however, dissolved oxygen varied from 9.0 mg/liter at night to 11.0 mg/liter during the day. Highest values were obtained at 1500 hrs at which time the oxygen content was 11.3 mg/liter, or 123 per cent of saturation. Vertically, a slight, but obvious, stratification of oxygen existed (Fig. 3).

FREE CARBON DIOXIDE. The free carbon dioxide content of Lake T-6 from surface to bottom was inverse to that of oxygen and exhibited conspicuous stratification throughout the 24-hr period (Fig. 3). Upper waters, to depths of 2-2.5 m, were gen-

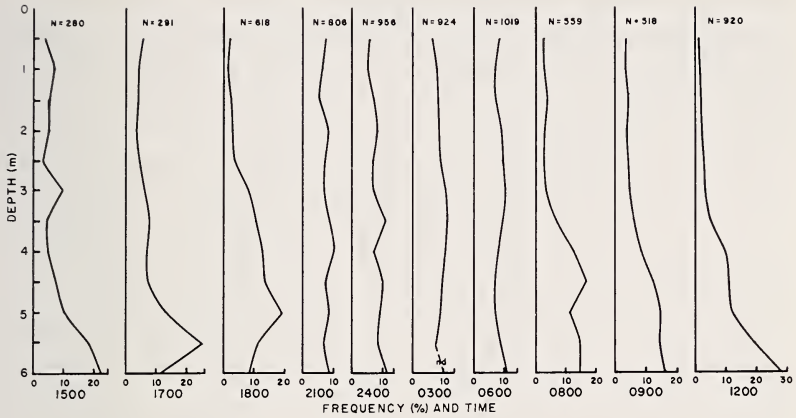

Fig. 4. Vertical distribution of *Mesocyclops edax* in Lake T-6 at the hours indicated. The value at each depth is per cent of the total catch through the water column shown in numbers ("N") above. Data are of 20-21 January 1964.

erally low (less than 1.0 mg CO_2/liter), and this correlated well with the high *p*H recorded at that level (Fig. 3). The CO_2 measurements, however, were within the range of error in the method used. But the concentration of the gas increased greatly below a depth of 3 m. At the bottom, all determinations (taken at 3-hr intervals) gave values between 8.0 mg/liter and 11.0 mg/liter.

HYDRONIUM ION CONCENTRATION. The *p*H of Lake T-6 surface waters ranged diurnally from only 8.0-8.2, and the bottom stratum varied from 6.0-6.8. This state is quite typical of phosphate pit lakes occasionally during winter, but constantly through the summer months. During the 8-9 January study, *p*H values were obtained only in surface and bottom waters, but from data taken at 1-m intervals in a near-by pit, the curve in Fig. 3 was constructed. Through the water column, *p*H related inversely to carbon dioxide content and it is likely that in the surface waters carbon dioxide was in the "bound" form as carbonates.

The Zooplankton

CYCLOPOIDA (CRUSTACEA: COPEPODA) The predominant cyclopoid in Lake T-6 in January was *Mesocyclops edax.* (Graciously identified by Dr. Gerald A. Cole, Arizona State

University, Tempe). This copepod was present throughout the vertical aspect of the lake at all hours, but in varying densities at given levels, and gave evidence of vertical migrations (Fig. 4).

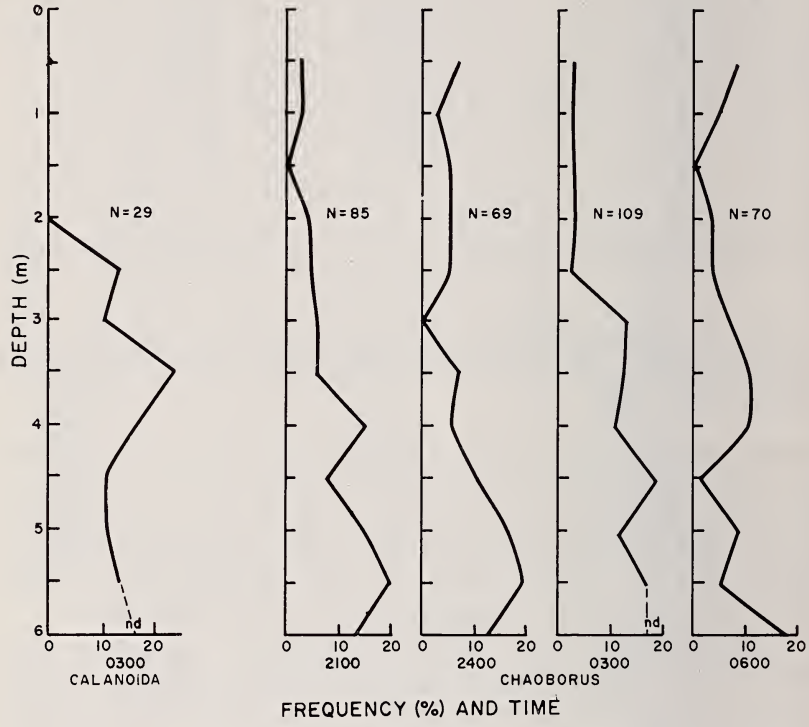

Fig. 5. Vertical distribution of Calanoida (left) and *Chaoborus* larvae (right). Values at each interval of depth are expressed as per cent of total catch through the water column ("N" figures above each graph). Data are of 20-21 January 1964).

The population density of *M. edax* increased conspicuously from sundown into the night of 20 January, reaching a maximum at 0600 hrs on 21 January. By 0800 hrs, the density through the lake was reduced nearly 50 per cent, with most of the population being concentrated in the lowermost 2 meters of water (Fig. 4). The noticeable increase in numbers at noon in Fig. 4 is interesting, and probably relates to the high turbidity of water and a response of the copepods to cloudiness which developed about 0900 hrs.

CALANOIDA (CRUSTACEA: COPEPODA). Unidentified

calanoid copepods came into the community at 0300 hrs; a total of 29 individuals was contained in seven 10-liter samples, and the population was confined to depths below 2 m (Fig. 5). In a preliminary study early in the month, calanoids entered our samples also at 0300 hrs and occurred irregularly until 1200 hrs, but always in numbers less than 6 individuals in twelve 10-liter samples at each sampling hour; the daylight period was marked by cloudy skies and a wind-rippled lake surface.

COPEPODA NAUPLII. Copepod larvae, the nauplii, occurred in considerable numbers throughout the diurnal investigation, but failed to fit any pattern, either temporarily or spatially, in the lake. The population density was greatest in samples taken at 0800 hrs on 21 January; the total in twelve 10-liter samples was 1,663 individuals, giving a mean of 13.8 individuals/liter at each half-meter level of depth. The lowest density encountered was at 1500 hrs on 20 January; the total number in 12 samples was 779, for a mean of 7 individuals/liter at each level sampled. At other hours the density varied considerably between the minimum and maximum.

CLADOCERA (CRUSTACEA). The cladoceran population was surprisingly sparse in Lake T-6; surprising because the animals are generally considered to be major components of lake plankton. The highest density in 10 periods of sampling was at 0800 on 21 January when the total number taken in 12 samples through the water column was 25, or 2.5 cladocerans/liter. At other hours the total number ranged downward to four. Data (unpublished) taken monthly at surface, mid-depth, and bottom for 15 months in a near-by pit revealed an even greater paucity of Cladocera; only two individuals were taken in all samples.

DIPTERA, (INSECTA). The larvae of an unidentified species of *Chaoborus* entered the plankton community from the benthos rather rapidly between 1800 hrs and 2100 hrs. At the earlier time, 14 individuals were taken between 4.5 and 6.0 m of depth, but by the later hour the total number in all samples had risen to 85 individuals/liter, and were distributed through the entire water column (Fig. 5). The dipterans remained planktonic in fair numbers until some time after 0600 hrs when they descended as rapidly as their earlier ascent. By 0800 hrs, only 6 individuals were captured throughout the water column.

Discussion

Extensive mining operations for land pebble phosphate in Polk and Hillsborough counties, Florida, have created a unique system of lakes of varying sizes. These are unique morphologically in that the sides of the basins are usually quite steep and allow for little or no littoral zone, and the bottom consists of a fine, flocculent material that may be several meters thick. The lakes are unique chemically in that during most of the year, high concentrations of ions prevail in the deeper waters, thus imparting high conductivity and total (methyl orange) alkalinity at that level. At that time, the *p*H decreases greatly with depth. During summer (and often at other times), carbon dioxide exists in upper waters in the bound (carbonate) form while free carbon dioxide is present in lower strata. The phosphorous content is high and contributes to the productivity of the waters. The lakes are interesting biologically primarily in terms of the plankton, for those lakes investigated thus far have been found to support only very meager populations of calanoid Copepoda and Cladocera. Even in view of all these features, lakes have escaped the intensive scrutiny of limnologists.

As one aspect of a more comprehensive comparative study of lakes of central Florida, we needed information on diurnal variations in the physico-chemical features and the zooplankton community in a phosphate pit lake, even though the investigation might be short-termed. January, which should be a rather quiescent period and one of minimum activity, was chosen as the time. (It is also the month of "independent study" at this college when students are free to pursue original lines of endeavor). Lake T-6 was chosen because of its close proximity to campus.

The two 24-hour investigations revealed that, chemically, the lake tended to remain relatively stable, at least with reference to oxygen, carbon dioxide, and *p*H. Turbidity was high and light transmission was low, and these conditions probably contributed to the rich carbon dioxide content of the deeper waters. Thermally, the water column of the lake responded to flucuations in atmospheric temperature, although deeper waters remained relatively uniform over the 24-hour period.

Biologically, it was interesting to find the dominant copepod

of the limnoplankton to be a species of the genus *Mesocyclops,* for this genus, according to Hutchinson (1967), tends to replace *Cyclops* as the "chief planktonic Cyclopoida" in subtropical and tropical regions. The paucity of Cladocera is enigmatic, for they are common in small natural lakes of the region. Rotifera were prominent in the plankton, but were not included in the present study. The brief appearance of calanoid copepods in the plankton poses another question, for in many natural lakes of the area, these animals occur in fair density through the water column during the day. The larvae of the dipteran *Chaoborus* were entirely absent from the plankton, at least from our samples, during diel hours, but were present from about 2100 hrs to shortly after 0600 hrs. This would appear to be the most typical pattern of migration of the insect. Hunt (1958), however, has reported *Chaoborus* in great numbers during the day through some 32 meters of depth in Deep Lake, Collier County, Florida. We do not propose to enter here into a discussion of the phenomena of vertical migrations, but rather prefer to refer to the excellent treatment of the subject by Hutchinson (1967.) and to recent studies on *Chaoborus* by LoRow (1968, 1969). It would appear, however, that phosphate pit lakes in south central Florida and water-filled limerock quarries in north central Florida, usually of high transparency, would be excellent sites for the study of migrations of organisms.

Acknowledgments

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